Chalking It Up: Advice to a New TA

Third Edition

Bruce Reznick
University of Illinois

Introduction

"The secret to education is respecting the pupil."
Ralph Waldo Emerson

Facing your first class is a frightening experience. Think of it! Thirty human beings have paid good money to a fine university for their education, and they have been entrusted to you. You represent three percent of their college instruction, and you have never taught before. What can you do? Plunge ahead. Erase the board, pronounce your name and spell it in chalk, tell the class your office address, phone number and e-mail address, identify the course by name and section number, hold up the textbook and describe the syllabus, announce your office hours and intended grading scheme. By the time you call the roll, you are already a teacher. Congratulations!

I am a professor of mathematics, not a professor of education, and I have not studied pedagogy in an organized fashion. This is a practical essay on teaching, anchored by a few underlying observations.

Remember that your students are just like you. You have probably been a student for most of your sentient life, so you know more about teaching than you may think. Try to recall what you didn't like as a student and don't do it as a teacher. After your first semester, you will find a new respect for your old teachers! **Remember also that your students are not at all like you**. You are interested enough in mathematics to pursue an advanced degree; your first students are likely taking a glorified high school course. As my mother said to me just before I taught my first class: "Be kind to your students. Math is much easier for you than it is for them." **Your students are not stupid**. Be patient with them. Try to remember how it felt to take your least favorite required course and keep in mind that many of your students will feel that way towards *your* course, no matter how well you teach. Some will always look forward to a math class in the way they look forward to a dental appointment. **There is more in the world than this**. Mistakes *will* happen. Nobody's perfect, ever; let alone the first time. (It's the first time you're teaching this course and it's also probably the first time your students are taking it.) As a graduate student, you can only allocate a limited amount of time and energy to your role as a teacher, and you must use these resources wisely. **Knowledge cannot be given, it must be taken**. Your students have also allocated a certain amount of time and energy to your class. Your job is to direct their efforts in the most fruitful directions, and trick them, if necessary, into doing the work that needs to be done. A proficient practitioner of educational judo can get a class to teach itself. **You are not alone**. You do not need Zorn's Lemma to see that every teacher has been a first-time teacher. When in doubt, ask a more experienced colleague. Almost any imaginable problem has occurred before. Recovery can be made from almost any disaster, but you need to act responsibly. For example, if you are unable to attend a scheduled class meeting, you must get in touch with someone in your department office, so the class can be covered. Finally, everything you read here is subject to an important local constraint: **In case of conflict, always follow the specific instructions of your department.**

Teaching can be extremely rewarding, but that is not why you have earned an assistantship. Your department has a lot of teaching to do. **Your primary job as a teacher is to convey as much of the course material as you can to as many students as possible**. There is no obvious optimal method. Any reasonable technique for increasing the transmission of knowledge (facts, theorems, techniques, examples, algorithms, perspectives, wisdom) is, by definition, a good teaching technique. Your own enjoyment of teaching may be important to you, but is secondary to the task at hand. By accepting a stipend, you have become a professional. In time, you will become a pro.

A good teacher must be productively manipulative. Almost every college student has the inherent ability to understand algebra, trigonometry and even calculus. The barriers to learning are psychological, environment and linguistic. **A good teacher will persuade students that they can learn the material**. Motivation to learn mathematics can be found everywhere, and even the most recalcitrant students want to pass. I have found in a wide range of courses and student populations that, if you take your students seriously, they will respond in kind. **Present yourself as an alpine guide to your class of climbers, rather than as part of the mountain**. Create an

atmosphere of common purpose rather than a battleground of wills. Encourage your students. Make them feel that, with time and effort, they *can* succeed. It's easier than you may think. Most people want to please those around them and your students have had a dozen years' experience pleasing their teachers (at least to their faces). Use this to your advantage. **Take your work personally**. Make it clear to your students that *you* want them to learn, that it matters to *you* whether they understand your presentations, finish the homework, pass the exams. Make the class a unique, individualized experience, and not just another soul-less exercise at the Big U. If you really care about your students' outcome and are even moderately successful in transmitting the material, then you will find teaching to be very rewarding. Students remember and appreciate good teachers. One can bask in the compliments of a satisfied customer for years to come.

Please meet now two caricatures of imaginary teaching assistants. Morrie assumes that his students are miniature versions of himself: brilliant (of course), deeply committed to learning the foundations and fine points of mathematics, and able to assimilate material like a vacuum cleaner. He doesn't bother to prepare his lectures, because the course is so trivial that one reading of the text is enough, and besides, his students should see how a *mathematician* approaches an unfamiliar situation. He cuts off stupid questions in class that waste his time and is forever annoyed that his stupid and lazy students don't make the minimal effort needed to understand him. He writes a very easy test, but half the class flunks. Morrie wonders how these idiots will ever find gainful employment after school. He should wonder how he'll support himself after they take away his assistantship. Lester, on the other hand, can't imagine how the poor children will survive without his constant attention. He has given out his *home* phone number and is available for consultation at all times. He gives two review sessions before each test and encourages students to ask for a make-up test if they aren't ready or have a bad day. He takes each student's imperfection on an exam as a personal failure. In fact, he is afraid to give zero credit for absent work, fearing its effect on his students' delicate self-esteem. Unfortunately, Lester neglects his own studies and will also be looking for another job next year. These are extreme, but not unknown, cases. They come in various intensities and genders and a little bit of them lives in every teacher, Morrie or Les.

The rest of this essay is divided into four sections -- preparing, lecturing, grading and copying. Ignore any suggestions that strike you as obvious or ridiculous, or so peculiar that you can't imagine yourself using them. You will soon develop your own teaching style. To paraphrase Tolstoy, **good teachers are good in their own way, but bad teachers are alike: they are unable or unwilling to communicate with their students.**

I happily acknowledge the suggestions of many friends and colleagues. In particular, Barry Cipra, Nancy Diamond, Dar-Veig Ho, Diem Kratzke, Tom Kratzke, Ray McEachin, Mark Meyerson, Beverly Michael, Larry Riddle and Korin Spongberg were helpful in preparing the first edition and sending me comments after it appeared. Judy Holdener critiqued the second edition and gave me valuable information about the role of teaching assistants in computer labs. Robin Sahner has probably read twenty drafts of both editions, and often saved me from blatant typos and subtle conceptual errors. Remaining mistakes are of course my full responsibility.

This guide was originally written for use in graduate student orientation at the University of Illinois. The generous response it elicited here encouraged me to seek a wider audience. The first edition was produced in 1985 through the auspices of John Martindale at Random House/Birkhauser for distribution as part of their textbook series, and was requested for use by more than sixty graduate programs. In 1993, George Duda at HarperCollins asked me to prepare a second edition and provided many useful suggestions of new topics. In 1997, the rights reverted to me. Tori Corkery has been instrumental in transforming this manuscript into html-ready form. I thank all of these fine people for their encouragement and cooperation.

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1. Preparing

"Mere proof won't convince me."
Caption to a cartoon by James Thurber

When you teach mathematics, you have an enormous advantage over the teachers in most other subjects: you can make statements in complete confidence of their truth. The value of a definite integral does not depend on political or religious beliefs. Consequently, the mathematics teacher has a special obligation to prepare classes carefully. **You must know what you are talking about, and you must know what you don't know.** It is far better to admit your ignorance to a class than to feign knowledge. The old cliche that you never learn a subject until you teach it happens to be a true cliche. After admitting "I don't know" (which will happen), you should prepare a full explanation for the next period. This special effort will show your students that you are responsive to their needs and will work for them, and this, in turn, will encourage them to work for you.

Your department will give you a syllabus that should tell you what to cover in each lecture. **Take the syllabus seriously!** In their nervousness, most beginning teachers talk too fast, cover too much and do not leave time for questions. Some examples must be left for the students to work out on their own. It is advisable to rehearse your presentations (at least in the first week) and write down the material you will put on the board. **Work out all calculations in detail and make sure you know the correct definitions.** Be reasonable. There is no mathematical reason why you can't have x as a constant and c as a variable in the same problem, but you will confuse most people seeing calculus for the first time, so it's a bad choice of notation. If you are running a recitation section, be prepared to present the solution to *any* homework problem, **using the methods you expect from your students.** Emphasize the algebra of computations and not the arithmetic. The biggest waste of class time comes from fumbling through examples with errors, false starts, etc. If you can't do the work, you make it easy for students to rationalize *their* not doing the work. Students should be actively involved in the class presentation. There is nothing unethical about asking them for suggestions when you already know what you want to do. Another old and true cliche is

that mathematics is not a spectator sport.

Arthur C. Clarke has written that a smoothly running advanced technology would be indistinguishable from magic. Formal mathematical proofs, stripped of tangible intuitive underpinnings fall into the same category. You should always prepare some sort of informal explanation for the mathematics in your presentations, even if, as in the case of trig identities, all you can say is "It turns out that...."

Morrie's rationalization for not preparing his lectures -- that it's good for students to see how a *mathematician* approaches an unfamiliar problem -- is commonly heard from new TAs and from world-renowned mathematicians. It is self-serving rubbish from anybody. There is no reason why you cannot explain your approach as you present a prepared solution. Unless you are teaching "*Thought styles of the smart and tenured*", your students are more interested in competency in their subject than in understanding how you tick. Most importantly, your behavior in the classroom presents a model for your students: your hours together constitute a small and limited intellectual utopian society. If you bluff and blunder your way through the class, you are validating your student's efforts to bluff and blunder *their* way through the class. Such is not the path to knowledge. Never forget that your students' lack of expertise in mathematics does not make them fools; they will spot a slacker and act accordingly. It is very hard to regain the respect of your students when you have lost it through preventable incompetence.

Nevertheless, it is a waste of time to prepare *too* carefully. Your presentations are for the moment, not for posterity. **Even the most brilliant lecture will leave many students befuddled. Do not take this personally**. Leave room in your preparation for questions and unplanned tangents. Many people need time to assimilate new material. If you are uncomfortable in English, communication must take precedence over spontaneity, but you should never ignore questions.

You should spend the first weeks of the term familiarizing yourself with the entire course. You must learn the particular notations of the text, even if they seem arbitrary or ungainly, since your students will be asking you questions in that language. Mathematics in a consistent set of notations is confusing enough. If you are running a recitation section, make sure you know what the lecturer has covered, especially where it diverges from the text. You should always have a rough idea of what you will be doing in the next few classes. Every topic lives in four tenses: "soon we shall consider...", "now we consider...", "now we understand..." and "you are responsible for...". If you announce a major topic in advance of covering it, you will enhance the sense of accomplishment upon its completion.

There are many unexpected resources for the preparation of your classes. Many texts have a teacher's edition. There are literally hundreds of textbooks in print for any course you are likely to teach as a TA. These provide an excellent source for the preparation of examples and test questions. Your department probably has a collection of unused complimentary textbooks sent by publishers. Shop around. Don't rely too heavily on a single alternative; an alert student might catch on. There are also relevant films and videotapes. These can break up the monotony of the long semester and are a good way to reward the serious students who show up in class the day before a holiday. Prowl the Web for additional enrichment ideas.

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2. Lecturing

"No dark sarcasm in the classroom."
Pink Floyd

So now that you have prepared for the class, you must face your students. According to pollsters, people are more afraid of public speaking than anything else. Two ways to reduce this fear are to be confident in your knowledge of the material and to create a congenial class atmosphere. Even if you shake visibly, remember that students are much more scared of a trembling teacher than vice versa. It does get easier with time.

Much of your job in the classroom will be specified for you by your department, but there are a few virtually absolute rules. **Arrive at your classroom as early as possible, and on time under all circumstances**. The interval before the bell can be put to productive use. You can individually return corrected work (and thereby match names and faces) and you can also talk to your students in a more relaxed way. If you establish yourself as a human being before the bell, then it is easier for you to assume the role of instructor once class starts. Promptness reinforces the notion that the time between the bells is special: teacher and student must behave differently than in ordinary life. Once the bell rings, you should start immediately on organization material (test dates, assignments, etc.) and old business. Review the work of the previous day and ask for questions. **Do not cater to late arrivals by waiting for their attention**. Time is precious. One minute a day, three times a week for a semester, adds up to a full class period. You'll need that period by the end of the term.

The same rules of courtesy apply to the end of the class. **Stop on time or, on rare occasions, one or two minutes late**. By the time the bell rings, the student has already stopped listening, and will not give your presentation the attention it deserves. Avoid the temptation to start a new topic late in the hour. You will almost certainly have to repeat everything the next time. Do not be afraid to stop lecturing a few minutes early, if you can think of no constructive use of the time and there are no questions, but don't do it often. **If possible, stay for a few minutes after class to answer short questions**. This is an efficient alternative to a short office visit for all concerned and reinforces the desired impression that you care about your students.

The mechanics of lecturing are straightforward, but hard to implement consistently. Write in a large, distinct and legible hand, so people in the back can see. (My former students should please stop snickering now.) If your chalk squeaks, break it in two and write with the broken edge. Stand alternately on either side of your writing, à la Vanna White on *Wheel of Fortune*, so that students on both sides of the

room can read your work, and pause long enough that it can be copied. Depending on the geometry of your classroom, the students in the back row may be unable to see as much as the bottom third of the board. Ask. **Speak clearly and slowly enough to be understandable**. Try to vary your pitch and tone, so the class will know when you're making an important point and so they won't be lulled to sleep by your monotone. Students with strong regional or international accents should be especially assertive in confirming their comprehensibility. Urge your students to let you know if they can't see or hear you. Establish eye contact with every student. (Harassment tip: the eyes are *above* the neck, even on students dressed for the beach.) Eye contact keeps the class alert and provides you with honest and immediate feedback. No matter how good you are, some students will be thinking about their next or their last date; don't let one distracted face throw you off stride.

Always ask for questions. **Never say that a question is stupid**! Every student who doesn't understand a point (and is brave enough to ask) represents many others who are afraid to raise their hand. **You may despair of your students' ignorance but remember that your job is to teach these people.** A curt reaction which suggests "You are an idiot, get out of my life" will both reduce the number of questions and stifle the learning process. Many people are turned off to mathematics for life by just one such arrogant teacher. Repeat questions to make sure everyone has heard them. When you answer a question, be patient and informative, and maintain eye contact to see if you've gotten through. It is proper to defer an answer to later in the hour or week, if new material will address the issue. The total absence of student questions, despite your sincere requests, may be a sign that your class is lost. When you get bogged down (it will happen), call "time-out", move ahead in your presentation and pick up the topic in the next class. I do not like to interrogate class members. This is college, not high school, and if students dread coming to class, they will simply not show up. Perhaps you are a more skillful interrogator than me.

Be sparing in use of words such as "clear", "trivial" and "easy" when referring to mathematical ideas. These provide little reinforcement to the good student and devastate the poor student. You will probably find yourself in greatest sympathy with your best students, since they are most similar to yourself. Do not skew the class solely to their interests. A "C" student pays the same tuition as an "A" student, and often will eventually contribute more to your department's development fund.

Never be afraid to repeat yourself. Nobody pays full attention all the time. Some ideas need to be heard a few times in order to sink in. Students are always reassured when they hear something they already understand. Never be afraid to repeat yourself.

After a dozen or more years of schooling, the student establishes a direct link from eye to hand, bypassing the brain. You should never intentionally write something incorrect on the board, even when you say it is wrong. Someone will be distracted and copy it down. Label the source of examples when they come from the text. This encourages students to study from the text as well as the class notes.

New teachers often wonder how they can make their lectures more interesting. The best way is for you to **show an interest in the subject yourself!** Don't just copy down the book's examples, change the numbers around. If you can calculate quickly, ask students to provide the values of some less essential parameters in your examples. Look for opportunities to pursue student questions, especially if they are in the direction you already want to go. If you have a particularly lively discussion one day about one specific mathematical object, be sure to return to that object again whenever feasible.

Showmanship in education is only worthwhile when it increases attendance or helps maintain class interest. If you like to tell jokes, tell jokes. **Avoid saying anything which might possibly offend anyone, and never make one of your students the object of humor**. This is not political correctness; this is common courtesy. Ethnic and sexual jokes are always inappropriate. Remember also that you are now an authority figure, it is inappropriate to smirk about how dumb Mr. X's mistake was or how hard the next test will be. **If you don't like to tell jokes, please don't tell jokes**. Nobody expects a math class to sound like a stand-up routine. Take my derivative, please.

The diversity of courses taught by TAs makes it hard to give specific advice about class content. Follow your syllabus and use it as a guide to pacing. Ask for help from your colleagues if you are having trouble keeping up or filling the hour. Present solutions in the straightforward way you expect your students to find them. Emphasize the unity, and reasonableness of the material, and de-emphasize the tricks and shortcuts. (A technique is just a trick you've seen before.) The level of rigor in a text may distress you, but do not raise it unilaterally. **Explanations are always preferable to proofs**. The appreciation of proofs is a sophisticated taste, and probably not one of the principal goals of your course. The most important part of a college education is learning how to think independently. Most of the low-level mathematics you are teaching is valuable as a tool in other disciplines, rather than an end in itself. Teach your students how to **read** mathematics.

Many departments now teach some beginning mathematics courses in computer laboratories, in which the roles of the instructors vary tremendously. You will probably be more comfortable with the mathematical component of the course than the computer component. You must become proficient in both and incorporate them into a unified course. Avoid the common arrogance of the mathematician who feels that anything non-mathematical is trivial. Do not underestimate the effort needed to understand the relevant computer work. The level of informality in the lab may make it hard to enforce the bells; you should find useful activities to keep the better students occupied for the full period.

There are at least five distinct media through which a student learns: the textbook, the classroom, the homework, the exams and out-of-class work with other students. Each medium is best suited for a different sort of learning. The most brilliant lecture series makes for a superficial or incomplete textbook, and the best textbook, if read aloud, would be ponderously dull. The text is best as a reference, used to learn material which requires reflection and careful study, and for detailed calculation and lengthy and precise definitions. The best use of the lecture is for real-time interaction with students, answering questions and presenting examples which show how things

"really" work. Handy hints and suggestive analogies which would be awkward in print are ideal for the lecture. Lectures are most effective when the students already have made some attempt to learn the material. I encourage my students to read the appropriate text sections both before and after the lecture. Some even do it.

Homework is essential for the assimilation of skills. However, problems should not be due before similar work has been done in class. Exams are not often considered a tool for learning. **The effort your class makes to study for your exams provides you an opportunity to focus attention on the crucial parts of the syllabus**. For this reason, I think it's foolish to be coy about the material you plan to test. Out-of-class interaction is largely beyond your control, but it is often the way students learn the most. I distribute a voluntary phone and e-mail list; some students will be understandably reluctant to give out this information, and you should never force them. At my school, I can arrange for newsgroups specific to each class. I make these unmoderated, and encourage class members to post.

I explicitly encourage students to work together on their homework, but this may violate the rules of your department. Check first! Assuming it is OK, I encourage the students to discuss the homework on the newsgroup before it is due. I also post any e-mail correspondence I have had with students, after anonymizing the source of the questions.

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3. Grading

"Be courteous, impartial and firm, and so compel respect from all."
General instructions to umpires, Official Baseball Rules (9.05).

In the ideal academic setting, there would be no testing and grading, just class discussions and the correction of assignments. Students would not need certification and would care enough about the content of their courses to make the stimulus of grades unnecessary. We are not in the ideal. Virtually every American university agrees on the need for some hour exams during the term and a final at the end. Writing, administering and grading these tests provide some of the most difficult and least rewarding aspects of the teaching profession.

You will probably be teaching one section of a multi-section course. and will be expected to provide a final course grade for each student. **It is essential that your grading schemes be consistent with those of your colleagues**. The components of a final grade usually consist of homework and/or quizzes, hour-long exams and a final. This section represents the current state of evolution of my personal taste as an autonomous instructor and is far from pedagogical dogma. As before, if what you read here contradicts the instructions you have been given, *ignore this material*!

Many teachers use weekly quizzes as a substitute for graded daily homework. I think this is a bad idea, but I am in a distinct minority. I think that quizzes absorb class time and merely replicate the exams in miniature. They tend to distort the entire class period in which they are given. There are few situations in the "real world" in which mathematics must be applied quickly and without reflection and without recourse to reference books or knowledgeable colleagues. Homework assignments more accurately simulate the circumstances in which students will use their mathematical knowledge. To be sure, graded homework assignments are more time-consuming for instructors than quizzes.

I assign homework to be due most class periods for a lower-level class, and weekly for an upper-level class. Not all problems are graded, but the students know in advance which ones will be graded. (Ungraded problems are used as the basis for some exam questions.) Students get a chance to test their skills without a time constraint and are encouraged to work steadily throughout the semester. Daily homework gives me a rapid and accurate idea of what my students have learned. I grade on a fairly crude numerical scale of 3 or 4 points per assignment, which minimizes hair-splitting discussions of partial credit. I drop the lowest few homework scores in computing homework percentage for the course, which minimizes arguments about whether a student should be excused from a particular assignment due to outside activities.

When the homework is due, I distribute worked solutions to all problems assigned. This fills many needs at once: it "extends the hour" by limiting the amount of class time I need to spend on routine homework problems; the homework grader can save time by referring the erring student to the worked solutions; I can justifiably refuse to accept late homework for credit (the bane of every grader and a bad study habit); by the end of the semester, students have a supplement of several hundred worked problems; finally, the fresh preparation of homework problems keeps the instructor's attention on the material. (You'll know what I'm talking about after teaching the same class for the third or fourth time.) It is possible that your department limits the number of handouts you can give your class. Check! Instructors sometimes make homework solutions available at the local campus copy shop or post solutions outside their office. Neither of these has the same immediacy as the scheme given here.

Homework assignments ought to require at least an hour's work per class for the average student, beyond reading in the text and reviewing class notes. I usually give homework on the fly, waiting for the end of the class period to put the next assignment on the board. This is not very popular, but allows me to tailor the assignments to the actual material covered. You should probably stick to problems from the text until you are an experienced instructor. I try to return homework by the next class period, so both the students and instructor get rapid feedback on what has been mastered. **Students will work together**. Many do their most productive learning in groups. If you encourage this, maybe some weaker students will copy a better student's homework without fully understanding it. (I confess I did this in college physics.) If you forbid collaboration, many students will still work together and you will have created a large group of scofflaws. In my opinion, this hurts the social contract of the class even more than the inequity of a student getting unearned credit through copying.

Your department may forbid collaboration, however.

Tests. You have done your best to explain the material and provide illuminating examples and have patiently collected the homework. **Some of your students will inevitably disappoint you on their test papers with egregious lapses of knowledge**. This is a fact of life. Some students only care about their grade in your course, which they regard as an annoying obstacle in their academic path. **Students always study the material on which they think they will be tested**. You can use this leverage to great advantage by testing the most important parts of the course. Let your students know what you consider the core knowledge, base the bulk of the homework on it, and then write boring and straightforward exam questions. **Deep creative thought should not be necessary for the construction or solution of an examination in a basic mathematics course**. I do not like to see difficult questions on marginal topics or "trick" questions on exams. These send an unduly cynical message about education. **You should not use your exams to prove to your students that you are smarter than them.** They will concede the point.

Many students for their part become pre-law majors before an exam, looking for loopholes in the syllabus. It is both merciful and efficient to tell a class that you have no intention of testing them on a particularly tricky offshoot of the main discussion. Students should learn to hit the fastball before worrying about the curve. You want them to concentrate their limited studying time on the most important topics. On the other hand, you shouldn't give away the store. It is a good idea to distribute review questions before a test, especially if you have taught the course before. This minimizes the unfair advantage of students who have access to fraternity and sorority files of previous tests. I have given up on review sessions unless the class is in an unusually panicky mood before an exam. These perpetuate the false idea that passing the exams (rather than learning the material) is the main purpose of the course. One final thought, be merciful: an exam should be a dipstick into the crankcase of a student knowledge and not just a shaft.

In writing a test, you should first identify the types of problems you expect your students to solve, and then write problems to fit. A good test should take a good ("B") student about forty-five minutes of a fifty-minute class period to complete, leaving some time to check the answers. **Always take the test yourself.** Some problems take longer to write out than you expect. If your test takes *you* forty-five minutes, then it is too long. You will want problems with a range of difficulties, with an "A"-caliber question to challenge the best students. However any problem which is only solved by one or two students is necessarily a bad problem for that particular class. Not only will it frustrate most of the students, but it will ruin the scores of those whose poor work habits make them spend most of their time on it. Make the first question relatively easy, to reduce the frequency of choking. You should always indicate the point value of each problem, and balance your allocation of points over the entire corpus to be tested. I think it is a good idea for instructors of the same course to collaborate in writing tests, especially if the exams will be given simultaneously. It is prudent however to assume that any two sections will have friends in common, so you do not want to duplicate the same problems without some variation in the numerical parameters.

Multi-part questions should be used with extreme caution. A foolish error on the first part of such a question destroys the testing value of the rest of the question, unless you are willing to give full credit for a correct answer in (b), based on incorrect information from (a). This takes a lot of time to grade. Cute story questions are also tempting, especially to a new instructor. Unfortunately, student literacy is often so low that many students cannot find the mathematical problem embedded within. **Prepare your tests carefully.** It is no fun to deal with the consequences of a botched question, and you are obligated not to make the students suffer from your mistake. Even when you have written a fair and careful exam, you may be nervous before you administer it. This is natural. You may also be made uncomfortable by the accumulated stress in a room of test-takers. Keep in mind that the reaction of a class during and immediately after an exam may be a poor reflection of their true performance. I have seen students grimace and tug at their hair during an exam, leave in a funk, and turn in a perfect paper.

Your course will have overall grading philosophy. Here's mine. I am generous in partial credit towards those who know how to do a problem, but make silly errors or miss relatively minor points. Care in working is useful, but most exams force students to work at a reckless pace and most students will be using silicon-based helpers when they later apply mathematics. **An exam should be graded problem-by-problem to standardize partial credit.** Correct a few papers first without assigning point values in order to get a sense of how partial credit will be needed. Make sure you grade the method, not just the answer. Don't write exam questions in which the correct answer is easy to guess. Mark clearly the first place where a student errs. Avoid correcting solutions in full detail; I ask my students to redo their incorrect problems informally as a tool for learning. **A successful exam is one which accurately measures the abilities of the students, not necessarily one which maps them neatly onto a set of five letters.** Consistency in grading is essential when teaching a multi-section class; do not make unilateral policy decisions. **Students deserve privacy regarding their grades; return the exams individually.** You will probably know some student better than others, and it is not unreasonable to "root" for an especially hard-working student. It is definitely not okay to grade students differently on the same work, based on your estimate of what they "really" knew. Finally, it is worth remembering that ungraded papers do not become easier to grade while marinating on your desk. Get the grading done as quickly as feasible. Your students really appreciate a rapid turnaround.

By the end of the term, both you and your students should have a pretty accurate expectation about the final. I like to give a two-hour exam in our three-hour slot. The final should cover the course material in a balanced way, including variations on most of the highlights of the course. It is reasonable to be less generous with partial credit for conceptual errors on final papers, since the material is being tested for a second time.

Your grading scheme should be consistent and well-publicized from the start. Your conscience must be your guide, but you must also be consistent with the standards established in the course. I prefer grading on a numerical basis throughout, assigning a letter grade only at the end. (Students naturally want to know how they are doing; you can give them a range of grades.) Numerical grades are more sensitive

to the information in the exam scores and are commonly used in large classes. In this case, a student with two low "A"'s and one low "B" will probably have a high "B" on average, but perceive a low "A" by majority rule. You should make your students aware of this possibility. I grade lower level classes as follows: the homework counts 10%, each of the three hour exams counts 20% and the final counts 40%. This adds up to 110%, so I drop the 10% with the lowest percentage. This cushions one bad test if the student has done good homework. I do not weigh class involvement in the course grade. There are two escape hatches in my scheme: any student who gets at least 96% on the final will get an "A" and any student who gets at least 75% on the final will pass the course. These make students feel better, but in practice rarely lead to a grade that would not otherwise be earned. I announce that the "A/B", "B/C" splits will be no higher than 90%, 80%, etc., but might be lowered, depending on how the class does. This gives students specific goals to aim for, while retaining the promise of a curve. You might be able to keep your grade records on a computer in your department. I am perhaps irrationally dubious of the security in such a set-up. Keep a back-up, in any case.

An amazing statistical fact is that students' scores tend to clump nicely into the various grades, except for a few exasperating borderline cases. **The first time you make up final course grades, you should show them to at least one more senior instructor for comments.** I still stay up nights at the end of the semester wondering whether I've given the correct grade. **Do not feel guilty if you flunk a student.** Most students who flunk have not put in the time and effort necessary to pass. The student who is working hard and still flunking should be encouraged, early in the term, to use one of the many support services your department provides or to engage a tutor. **It is never appropriate to tutor one of your own students beyond the usual office hours, particularly for pay.**

Do not be talked into changing a student's grade by a hard-luck story. You would be surprised at how many hard-luck stories are not quite ... accurate. At virtually every university, one bad grade in one course does not get a student in trouble. Your school does not want to admit that its Admissions Office goofed, and so has an elaborate apparatus for handling students in hot water. A crucial part of this apparatus is the objective evaluation of a student's performance from a professional instructor. That means you. If you feel that a course grade does not represent the full story of a student's work, give the grade earned and get in touch with the appropriate dean. **Do not be reluctant to pass such problem students on to a more senior instructor or administrator in your department.** Teaching provides many opportunities for self-delusion. A good grade or a bad grade on a poorly designed test may be close to meaningless. Morrie and Lester would undoubtedly have radically different opinions about the same students. Maybe your class is stupid, or maybe you gave them two problems too many on their tests. When your median score is 93%, let someone look over your tests and grading policies. Maybe you're the next Jaime Escalante and your students are brilliant, or maybe you are not expecting enough of them. Even experienced instructors stay up nights wondering about these issues.

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4. Coping

"I was thrown out of NYU for cheating on my metaphysics final. The professor caught me looking into the soul of the boy sitting next to me"
Woody Allen

This last section is a miscellany of canned advice for dealing with unexpected difficult questions. I offer no warranty for my suggestions, because individual cases vary so much. **Again, always ask more experienced instructors for advice!** Some of the most useful information comes from listening to the "war stories" swapped by your department's grizzled veteran teachers. Professors can help, too.

Cheating can be a profoundly troubling problem. **The truly dedicated cheater is probably close to undetectable.** There are students who put more effort into cheating than they would need to pass the course honestly. The best vaccine is an atmosphere of common purpose in which cheating is perceived as antisocial and destructive -- an offense against the majority of honest students and an assault on the integrity of the educational system. Many cheaters justify their actions as a response to the indifference of their instructors. Never give them this excuse. Peer pressure can be an effective preventive. Remind your students not to cheat in a friendly "I-know-you-wouldn't-do-this-to-me" way. **Proctor exams with care.** Move around the classroom, including the back if possible, so prospective cheaters have no protected angles. Look at the directions of your students' gazes, but do not be too zealous. Many honest students look straight ahead when they think. If you are suspicious of a student, make eye contact until it is acknowledged. This is usually enough. Minimize the opportunities for out-of-class cheating by circumspect treatment of test materials. Write the test at home, after the last class meeting, if possible, and personally operate the copier which produces the exams.

When grading a test, be suspicious of non-sequiturs in reasoning, or oddly missing steps in the calculation. Be suspicious also of friends who sit together at an exam and make the same errors. (However, this behavior may have an innocent explanation: students who study together often share misconceptions.) Cheating is a serious charge to make, but you are well within your rights to ask that friends not sit together at the next test, especially if you do it tactfully. If you unambiguously catch a cheater, let someone in authority know immediately. Most universities have rather complicated regulations on cheating. These may strike you as lax. I announce that "nobody has ever cheated in one of my classes . . . twice", with a deliberately ambiguous smile.

Students often complain about the grading of their work. They may point out something the grader missed or claim that they deserve more credit. In either case, they deserve a serious hearing. If you see no merit in their case, tell them so. Otherwise, take the work back and review the grading on your own time, away from their scrutiny. Be reluctant to change your mind on a judgment call. Even as a new teacher, you are a professional with a richer perspective on the course material than your students. But grading mistakes must be acknowledged and corrected, on all relevant papers if warranted. Again, you may want to consult a more experienced instructor for

advice. Some unscrupulous students have been known to amend their papers after they have been graded and returned, and demand more credit. This is hard to prove. You should always make a mark on a blank examination page, to discourage after-hours inspiration. You can also photocopy an exam before returning it in hopes of snaring the repeat offender.

Teachers at the University of California are required by state law to post their office hours. It seems that an Assemblyman's son could never find his professor. In any case, this is an excellent idea. Most departments require their instructors to reserve two or three hours per week for answering questions, meeting absent students. etc. Most students are comfortable with email, and I've found that if you can respond quickly, you can handle much of the demand for office hours. You should also make yourself available for other appointments, but setting fixed hours is a good time-management technique. Do not expect a lot of activity until just before a test. Office hours are a good time to prepare for your classes and grade homework, and they provide a safety net for students, but they are an inefficient teaching medium. **If two people ask you the same question outside of class, you are well-advised to cover it in class.**

Many mathematicians are naturally shy people who find it hard to maintain the self-image of authority in the classroom. **Always remember that you have the superior knowledge and the power to assign grades.** When you see a student learn as the result of your efforts, your own self-confidence as a teacher (and in life) will grow. Mine did. This brings me to the issue of unruly students. It is hard to give general advice; books have been written on the subject. I start with polite requests and try to get the rest of the class on my side. If necessary, you can ask the offending party to leave. **If you have trouble keeping the attention of the class, silence is the best weapon.** Stand at the front, look annoyed (this part is easy), and say nothing, Do not speak until you have regained their attention. It will seem like forever, but fifteen seconds is usually all it takes.

Gilbert Highet noted that a teacher must be friendly without becoming a friend. However relaxed your classroom atmosphere, you must retain a proper distance from your students. You are in a power relationship with them, you are not equals. You cannot let personal relationships interfere with professional responsibilities. **Never date a student!** Not only is this unprofessional, it is almost certainly considered sexual harassment by your university. Avoid even the suggestion of an inappropriate personal interest in your students' lives. A prominently displayed photograph (authentic or not) of you in a couple will discourage inappropriate student interest in your life. In cases of sudden true love, I counsel patience or a change of section.

As a new teacher, you will be bombarded with advice, much of it contradictory and confusing. You cannot possibly accept it all. **Teaching becomes easier with experience.** You will discover that many obvious ideas fail and many dubious ideas work. Before long, you will be giving advice to new instructors and swapping your own war stories. I thank you for reading this far -- I think I'll let you out a few screens early.

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5. Further Reading

There are many articles and books which give advice to teachers. One classic is "The Art of Teaching" by Gilbert Highet. A large number of teaching guides, including the first edition of this one, are reprinted in "Keys to Improved Instruction", edited by Bettye Anne Case, MAA Notes No. 11. See also "How to Teach Mathematics: a personal perspective" by Steve Krantz. Steve, like me, is a research mathematician with a commitment to teaching. You might find any or all of these to be extremely helpful in developing your teaching style. As you become more proficient in the basics of teaching, you will want to read more systematically. Most of the journals published by the MAA contain useful articles about teaching techniques in every issue. Your department probably has some faculty members who can direct you to other resources.

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6. About the Author

Bruce Reznick is a Professor of Mathematics at the University of Illinois at Urbana-Champaign. He received his degrees from Caltech (BS, 1973) and Stanford (Ph.D., 1976). He has been a Sloan Foundation Fellow and Chairman of the Problems Committee for the Putnam Competition. His research ranges promiscuously among number theory, algebra, analysis, geometry and combinatorics. He roots for the Chicago Cubs, but has forgotten why. The author was supported in part by the National Science Foundation.

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